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ABSTRACT

This study investigated the role that spatial ability has in achievement in organic chemistry. Spatial ability was defined as containing two subfactors--spatial visualization and spatial orientation. Spatial visualization is the ability to mentally manipulate pictorially presented stimuli; involved in the processes of manipulation are the abilities of recognition, retention, and recall of a configuration in which there is movement along the internal parts. Spatial orientation is the ability to remain unconfused by changing orientations in which a configuration may be presented. Subjects were students in a course designed for nonscience majors, particularly for students in agriculture and health sciences. Findings show that students in the low spatial group scored significantly lower than students in the high spatial group on the organic chemistry examinations. Similarities and differences between the work of the high and low spatial students were also examined. The high spatial students made more use of drawings than the low spatial students on questions that asked for drawings and also on questions that did not ask specifically for drawings. It was also found that students, regardless of spatial ability, who drew pictures, scored higher on the examinations. (JN)

# THE ROLE OF SPATIAL ABILITY AND ACHIEVEMENT IN ORGANIC CHEMISTRY

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THE ROLE OF SPATIAL ABILITY AND ACHIEVEMENT IN ORGANIC CHEMISTRY

Organic chemistry is a field that relies upon the use of two-dimensional structures and figures to represent three-dimensional molecules. This study looked at the role of spatial ability in the success of students in organic chemistry. One would expect to see a positive correlation between spatial ability and achievement in organic chemistry. Spatial ability for this study was defined as containing two subfactors: Spatial Visualization and Spatial Orientation as described by McGee. Spatial Visualization is the ability to mentally manipulate pictorially presented stimuli. Involved in the processes of manipulation are the abilities of recognition, retention, and recall of a configuration in which there is movement among the internal parts. Spatial Orientation is the ability to remain unconfused by changing orientations in which a configuration may be presented.

Studies done by McMillen and Bodner and Carter, LaRussa, and Bodner showed that spatial ability is a factor in the success of general chemistry students. Their results showed that students with high scores on spatial tests are more likely to score high on both spatial and nonspatial tasks in chemistry. Their work also gives support for the use of a composite spatial score as a measure of spatial ability rather than relying on the result of a single test.

Spatial Orientation was measured using the Purdue Visualization of Rotations Test (ROT) (slide 1) and Spatial Visualization was measured using the Find a Shape Puzzle (FASP) (slide 2), an embedded figures test. Scores were then standardized and combined

to get a total spatial score for each student in this study. Achievement was measured by students' exam scores in an organic chemistry course. The course used in this study was a one semester organic course designed for non-science majors, especially for those students in agriculture and health sciences. There were 127 students involved in this study at the beginning of the semester and 104 students involved at the end of the semester. The reliability coefficients for the ROT and FASP are shown in this slide (slide 3).

There were five, 100 point exams given in this course. The exams consisted of multiple choice, short answer, essay, structure drawing, nomenclature, and synthesis questions. The means, standard deviations, and the number of students taking each exam are shown in the next slide (slide 4). The numerical values for the final grades were 5-1 for A-F respectively.

The students were classified into three spatial groups. The students scoring one-half a standard deviation below the mean on spatial tests were classified as low spatial, those scoring one-half a standard deviation above the mean were classified as high spatial, and students scoring within one-half a standard deviation of the mean were classified as middle spatial. The analysis of variance shows that for the combined spatial score there was a significant difference in the means of the three groups and there was no main effect for sex nor was there a significant two-way interaction between the combined spatial score and sex (slide 5).

To further investigate which groups were different, Scheffé's Test was used. The results of this test showed that the low spatial group was significantly different from the high spatial group on all exams and the final grade (slide 6).

The strength of the relationship between spatial ability and achievement in organic chemistry is weak but positive as shown in the the next slide (slide 7). The Pearson's correlation coefficients range from 0.16 to 0.39; thus spatial ability accounts for up to 15% of the variance in the scores on the organic exams.

The next step in this study was to look at the work of the low and high spatial students to see if any differences or similarities could be seen. Throughout the semester certain types of questions were repeated in several exams. These types included: draw-a-structure, write-a-mechanism, write-a-synthesis, complete-the-reaction, name-the-structure, and multiple choice. After looking at the analysis of variance for each part it was decided that four classifications would be looked at in more detail, those classifications were compound-naming, structure-drawing, synthesis-writing, and reaction-completing. These four types of questions showed the most significant difference between the spatial groups. The figures shown in the following slides are taken from the top ten and the bottom ten spatial students.

All of the exams used names in connection with other types of questions. The next slide (slide 8) shows the responses of several high and several low spatial students to a question asking for the name of a structure. Notice how the high spatial students

either redrew or added onto the the existing structure, while the low spatial students did redraw the structure but failed to start counting from the correct end. This, again, is shown in the next slide (slide 9), when the students were asked to name a Newman Projection. The high spatial students correctly redrew the structure while the low spatial students seeemed to have problems interpreting the structures they drew.

The students were asked to draw structures on all the exams. The next slide (slide 10) shows typical high and low spatial students' responses to structure drawing questions. The high spatial students often drew a preliminary structure before drawing the final one. The high spatial students were better at drawing with cleaner, well proportioned drawings that had good symmetry with little distortion. Many of the drawings of structures done by the low spatial students were lopsided, ill-proportioned, and nonsymmetrical. This was especially true in the case of drawing the phenyl group. While it is true that the low and the high spatial students do differ in their drawing skills, no student was penalized because of poor drawing skills.

One of the difficulties the low spatial students had with writing a synthesis for the preparation of a compound was the starting step. Few of the low spatial students could draw the correct structure for isopropyl alcohol (slide 11). Again, we saw the problem the low spatial students had with naming and structure drawing.

The last type of question looked at in this study was complete- the-reaction. Students were asked to complete the reaction by drawing the missing reactant, products of reagents. High spatial students tended to draw mechanisms and additional structures when answering these types of questions. The low spatial students did not draw as many additional structures as the high spatial students. The drawing of structures when done by the low spatial students did seem to help in answering the question (Slide 12).

Students who drew additional structures for complete-the-reaction, name-the-compound, draw-the-structure, and write-the-synthesis questions usually scored higher than those students who did not draw additional structures. This is especially true for the low spatial students. Also the low spatial students had difficulty naming structures the entire semester.

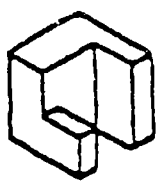
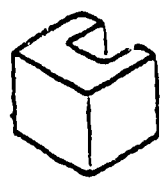
References

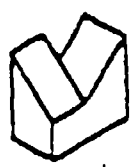
Carter, C.S., LaRussa, M.A., and Bodner G.M., " Spatial Ability in General Chemistry," NARST, French Lick, IN, 1985.

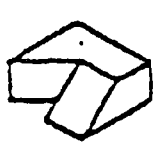
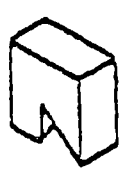
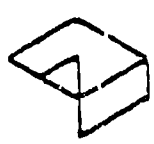
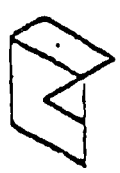
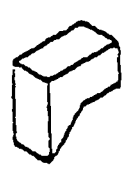
McGee, M.G., Human Spatial Abilities: Sources of Sex Differences, Praeger Publishers, New York, 1979.

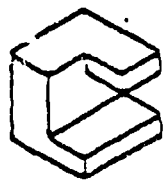
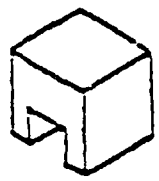
McMillen, T.L.B., and Bodner G.M., "Cognitive Restructuring as a First Step in Problem Solving," NARST, French Lick, IN, 1985.

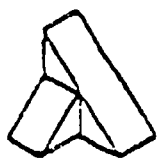
Slide 1

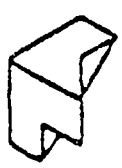
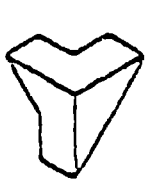
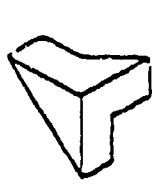
17  IS ROTATED TO 

AS  IS ROTATED TO

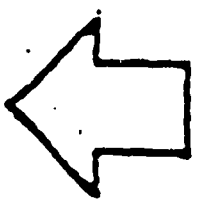
A  B  C  D  E 

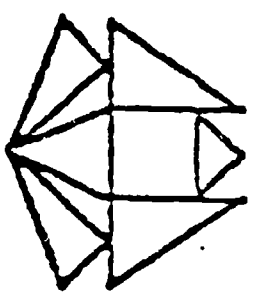
18  IS ROTATED TO 

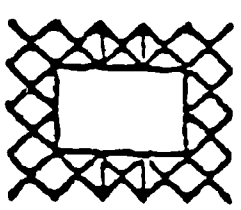
AS  IS ROTATED TO

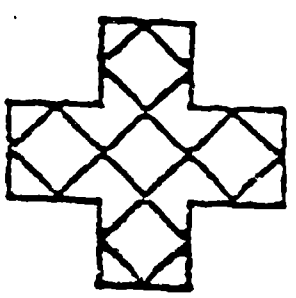
A  B  C  D  E 

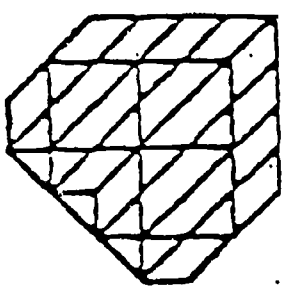
Slide 2

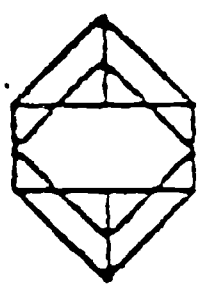












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DO NOT TURN THE PAGE UNTIL YOU ARE TOLD TO.

Slide 3

| | | | | |
|---|---|---|---|---|
| Chem 257 | Exam 1 *** | | .84 | .34 |
| | Exam 2 | | .84 | .82 |
| | Exam 3 | | .84 | .82 |
| | Exam 4 | | .82 | .82 |
| | Exam 5 | | .82 | .80 |

*Spearman-Brown Split-Half Coefficients
**Cronbach's Alpha Coefficients
***Reliability Coefficients were calculated for each exam due to the changing population from students dropping the course.

Slide 4

Means and Standard Deviations

| | EXAM | | ROT* | | FASP* | | |
|---|---|---|---|---|---|---|---|
| | MEAN | STD.DEV. | MEAN | STD.DEV | MEAN | STD.DEV. | N |
| EXAM 1 | 73.8 | 17.3 | 12.3 | 4.0 | 12.8 | 4.7 | 127 |
| EXAM 2 | 63.4 | 18.3 | 12.3 | 4.0 | 13.2 | 4.6 | 116 |
| EXAM 3 | 50.7 | 18.4 | 12.6 | 4.0 | 13.5 | 4.4 | 109 |
| EXAM 4 | 40.6 | 23.9 | 12.5 | 4.0 | 13.3 | 4.6 | 108 |
| EXAM 5 | 62.2 | 24.5 | 12.5 | 3.9 | 13.4 | 4.4 | 104 |
| GRADE | 3.4 | 1.1 | 12.5 | 3.9 | 13.4 | 4.4 | 104 |

*ROT and FASP were given only once. The mean and standard deviation was calculated for each exam due to students dropping the course.

Slide 5 and 6

F Values from ANOVA

| | EXAM 1 | EXAM 2 | EXAM 3 | EXAM 4 | EXAM 5 | GRADE |
|---|---|---|---|---|---|---|
| TROT | 4.7* | 2.2 | 4.2* | 2.1 | 1.0 | 2.0 |
| SEX | 0.0 | 0.2 | 0.7 | 1.2 | 1.2 | 0.3 |
| TROT X SEX | 0.7 | 1.2 | 1.0 | 1.8 | 0.6 | 0.9 |
| TFASP | 6.7* | 4.2* | 1.1 | 0.2 | 0.7 | 1.4 |
| SEX | 1.4 | 0.0 | 0.0 | 0.1 | 0.3 | 0.0 |
| TFASP X SEX | 0.6 | 0.6 | 0.2 | 0.8 | 0.3 | 0.1 |
| TSPAT | 7.9* | 6.5* | 5.8* | 4.0* | 5.8* | 9.1* |
| SEX | 0.2 | 0.2 | 0.3 | 1.0 | 1.2 | 0.2 |
| TSPAT X SEX | 1.7 | 3.0 | 0.3 | 2.4 | 0.6 | 0.9 |

*INDICATES SIGNIFICANCE AT OR BELOW THE 0.05 LEVEL

Results From Scheffe's Test

| | | | | |
|---|---|---|---|---|
| EXAM 1 | TSPAT | 67.2 (1) | 72.4 (2) | |
| | | | 72.4 (2) | 81.7 (3) |
| | TROT | 67.4 (1) | 74.7 (2) | |
| | | | 74.7 (2) | 78.7 (3) |
| | TFASP | 65.8 (1) | 74.1 (2) | |
| | | | 74.1 (2) | 79.8 (3) |
| EXAM 2 | TSPAT | 57.8 (1) | 61.1 (2) | |
| | | | | 71.9 (3) |
| | TFASP | 54.9 (1) | | |
| | | | 65.7 (2) | 66.6 (3) |
| EXAM 3 | TSPAT | 43.1 (1) | 50.5 (2) | |
| | | | 50.5 (2) | 58.4 (3) |
| | TRC. | 42.8 (1) | 52.8 (2) | |
| | | | 52.8 (2) | 54.7 (3) |
| EXAM 4 | TSPAT | 33.0 (1) | 39.6 (2) | |
| | | | 39.6 (2) | 49.1 (3) |
| EXAM 5 | TSPAT | 55.4 (1) | 58.0 (2) | |
| | | | | 73.6 (3) |
| GRADE | TSPAT | 3.0 (1) | 3.1 (2) | |
| | | | | 4.0 (3) |

NUMBERS REPORTED ARE THE MEANS FOR THE GROUP WHERE (1) IS LOW, (2) IS MIDDLE, AND (3) IS HIGH SPATIAL CLASS.

Slide 7

Pearson Correlation Coefficients

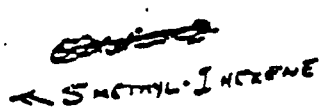
| | EXAM 1 | EXAM 2 | EXAM 3 | EXAM 4 | EXAM 5 | GRADE |
|---|---|---|---|---|---|---|
| ROT | 0.24* | 0.16* | 0.28* | 0.20* | 0.19* | 0.25* |
| FASP | 0.39* | 0.25* | 0.23* | 0.19* | 0.23* | 0.25* |
| TSPAT | 0.37* | 0.25* | 0.31* | 0.24* | 0.26* | 0.31* |

* INDICATES SIGNIFICANCE AT OR BELOW THE 0.05 LEVEL

Slide 8

IV. (24 points) Provide IUPAC names for each of the following:

b) 



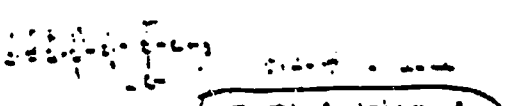
b) 

5-methyl-1-hexene

b) 

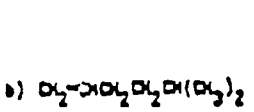
5-methyl-1-hexene

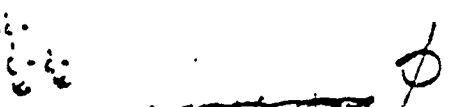
b) 

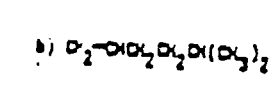


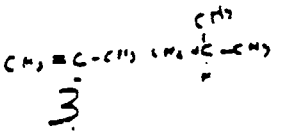
5-methyl-1-hexene

IV. (24 points) Provide IUPAC names for each of the following:

b) 



b) 



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b) 

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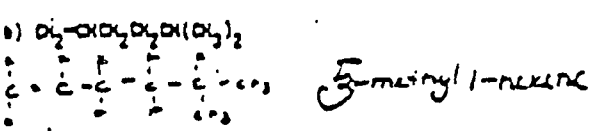
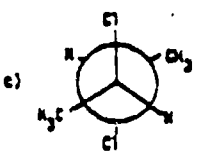
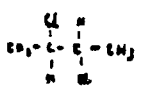


5-methyl-1-hexene

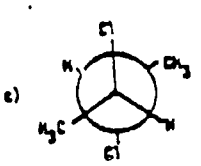
Selected Responses to Naming Compounds Question. Exam 1, part IV, b. High spatial students on top and Low spatial students on bottom.

IV. (24 points) Provide IUPAC names for each of the following:

c) 



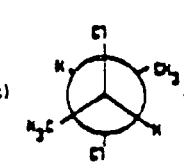
2,3-dichlorobutane

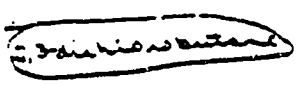
c) 

← 2,3-dichlorobutane

c) 

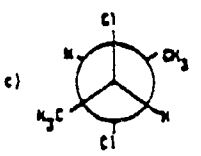
2,3-dichlorobutane

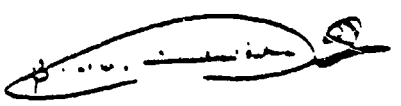
c) 

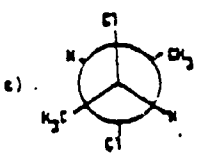


2,3-dichlorobutane

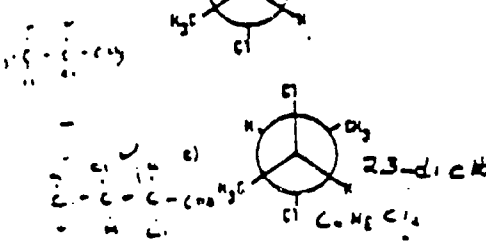
IV. (24 points) Provide IUPAC names for each of the following:

c) 



c) 

1,2-dichlorobutane

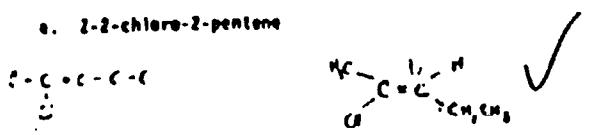


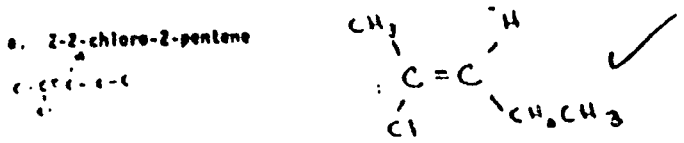
c) 2,3-dichlorobutane

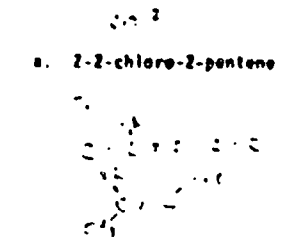
Selected Responses to Naming a Newman Projection. Exam 1, part IV, c. High spatial students on top and Low spatial students on bottom.

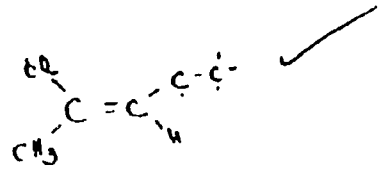
VII. (12 points) Draw complete structures for each of the following:

a. Z-2-chloro-2-pentene



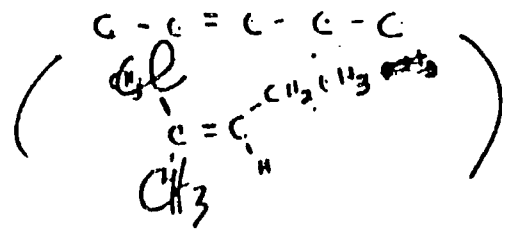


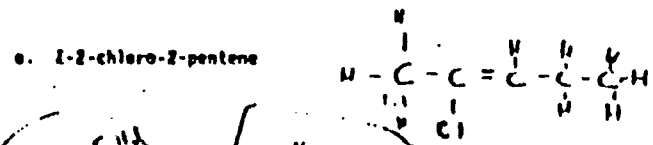


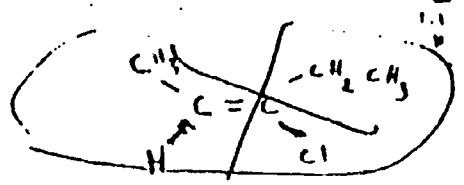


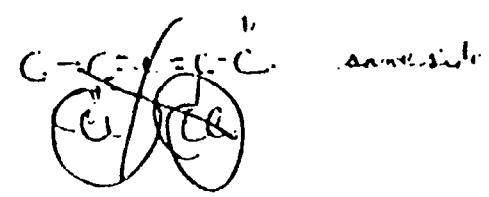
VII. (12 points) Draw complete structures for each of the following:

a. Z-2-chloro-2-pentene

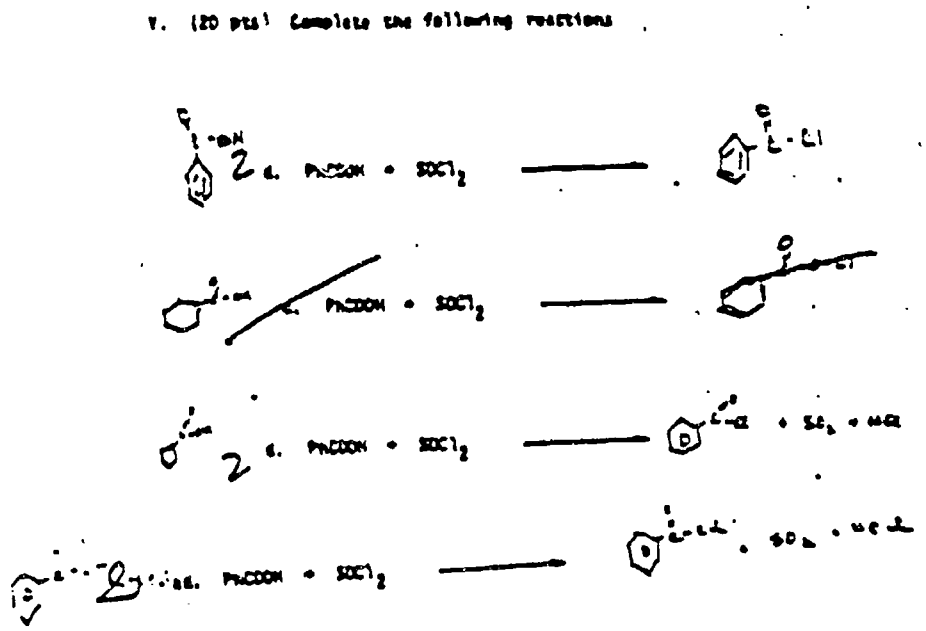


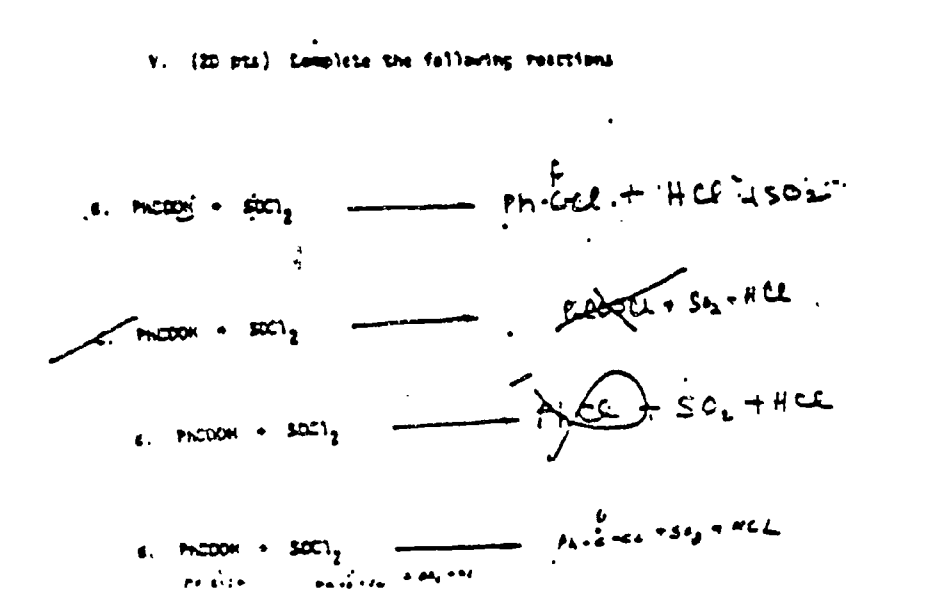






Selected Responses to Structure Drawing Question. Exam 2, part VII, a. High spatial students on left and the Low spatial students on the right.




Selected Responses to Reaction Completion Question. Exam 5, part V, d. High spatial students on top and Low spatial students on the bottom.

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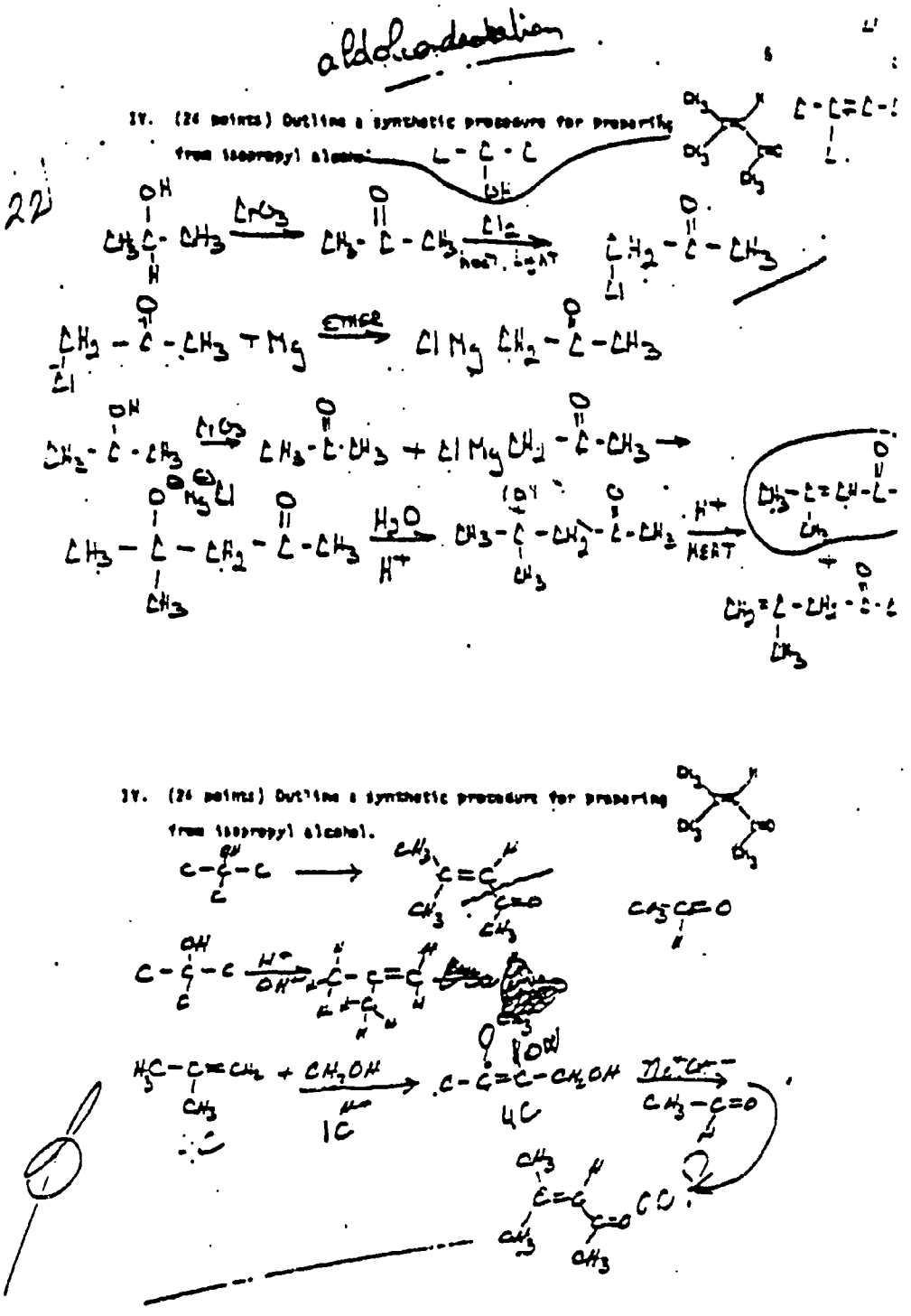


Selected Responses to Write a Synthesis Question. Exam 4, part IV. High spatial student on top and Low spatial student on the bottom.